



Farmers' Participatory Soil Erosion Assessment and Soil Conservation Improvement

Gizaw Desta and Hans Hurni

2011

Farmers' Participatory Soil Erosion Assessment and Soil Conservation Improvement

Farmers' Participatory Soil Erosion Assessment and Soil Conservation Improvement

Application of Local Erosion Indicators

Gizaw Desta and Hans Hurni

2011

Amhara Region Agricultural Research Institute (ARARI), Ethiopia, and
Centre for Development and Environment (CDE), Switzerland

Publisher:

ESAPP-CDE

Bern, 2011

This study and the publication of this report were funded by Eastern and Southern Africa Partnership Programme (ESAPP). Additional financial and logistic support came from CDE (Centre for Development and Environment), Bern, Switzerland.

Citation:

Gizaw Desta and Hans Hurni, 2011

Farmers' Participatory Soil Erosion Assessment and Soil Conservation Improvement. Application of Local Erosion Indicators.

Amhara Regional Agricultural Research Institute (ARARI), Ethiopia, and Centre for Development and Environment (CDE), University of Bern, 2011

Publisher:

CDE-ESAPP

Printed by:

Kopierzentrale der Universität Bern, Switzerland

Copyright© 2011 by:

ARARI and Centre for Development and Environment (CDE)

This study and the publication of this report were funded by Eastern and Southern Africa Partnership Programme (ESAPP). Additional financial and logistic support came from CDE (Centre for Development and Environment), Bern, Switzerland

English language editing:

Theodore Wachs

Layout:

Simone Kummer, Centre for Development and Environment (CDE), University of Bern

Cover photos:

By the authors

Digital copies of this report can be obtained from:

www.cde.unibe.ch/Regions/ESAPP_Proj_Rs.asp

Eastern and Southern Africa Partnership Programme (ESAPP)

Centre for Development and Environment (CDE)

University of Bern

Hallerstrasse 10

CH-3012 Bern, Switzerland

Tel ++41 31 631 88 22

Fax ++41 31 631 85 44

E-mail info@cde.unibe.ch

www.cde.unibe.ch

Table of Contents

List of Figures	iii
List of Tables	iii
Abbreviations	iii
Preface	v
Purpose of the Manual	v
Acknowledgements	vi
1 Introduction to Soil Erosion Assessment and Soil Conservation Planning	1
1.1 Introduction	1
1.2 State of soil erosion and soil conservation in Angereb watershed	2
1.3 Guidelines for soil and water conservation	3
1.3.1 Assessment of Current Erosion Damage (ACED) by Karl Herweg (1996)	3
1.3.2 Guidelines for Development Agents on Soil Conservation in Ethiopia by Hans Hurni (1986)	4
1.3.3 Community-based participatory watershed development (MOARD, 2005)	4
1.3.4 Gaps and issues to be addressed	5
2 Farmers' Participatory Soil Erosion Assessment and Soil Conservation Improvement	7
2.1 Concepts and the need for a participatory approach by farmers	7
2.2 Benefits of the participatory approach	7
2.3 Objectives of the new approach	8
2.4 Procedures for soil erosion assessment and soil conservation improvements	8
3 Assessment and Measurement of Erosion Indicators	11
3.1 Application of erosion indicators	11
3.2 Description and measurement of erosion indicators	12
4 Assessment of Soil and Water Conservation Measures	19
4.1 Performance of stone terraces	19
4.1.1 Technical assessment	19
4.1.2 Farmers' assessment of terraces	21
4.2 Assessment of traditional ditches and cutoff drains	22
4.3 Evaluation criteria for the assessment of soil conservation measures	24
5 Improvements in Soil and Water Conservation Measures	25
5.1 Improvement options	25
5.2 Appraisal of catchment-level improvements using new approach	28
6 Conclusion	31
References	33
Annex	35

List of Figures

Figure 1	Formation and development of rill erosion on the area between terraces	12
Figure 2a	Sediment accumulation behind soil bund structures	13
Figure 2b	Sediment accumulation behind stone check dams for different storm events	14
Figure 3	Evidence of tillage erosion underneath stone terrace structures	14
Figure 4	Runoff erosion and sediment lost from traditional ditches on farmers' plots	15
Figure 5	Active gully damage and associated landsliding	17
Figure 6	Diagram showing farmers' level of awareness for different local erosion indicators	18
Figure 7	Improved terrace structures with runoff water collection trenches	26
Figure 8	Improved terrace structures planted with high-value spice plants	26
Figure 9	Improvement on the cross-section of terrace structures	27
Figure 10	Old terrace structures shifted downslope	27
Figure 11	Series of check dams constructed along pathways	28

List of Tables

Table 1	Soil erosion impact indicators (as seen by farmers)	3
---------	---	---

Abbreviations

ACED	Assessment of Current Erosion Indicators
ALEI	Assessment of Local Erosion Indicators
ARARI	Amhara Region Agricultural Research Institute
CDE	Centre for Development and Environment
EGS	Employment Generation Schemes
ESAPP	Eastern and Southern Africa Partnership Program
FPEASCI	Farmers' Participatory Erosion Assessment and Soil Conservation Improvement
LLPA	Local Level Participatory Approaches
MOARD	Ministry of Agriculture and Rural Development
PADETS	Participatory Demonstration, Extension and Training System
SCRIP	Soil Conservation Research Program
SWC	Soil and Water Conservation

Preface

This manual addresses processes of farmers' participatory approaches and joint learning procedures for improving the efficiency of soil and water conservation measures. It offers information on how to assess erosion and soil conservation, plan and improve individual and communal soil conservation activities through field visits, exchange knowledge and experiences, and engage in continuous dialogue. It provides information on procedures and methods of assessing and improving soil conservation for farmers who are organized in a topo-sequence and/or at catchment scale by integrating individual farms. This effort is particularly important at a time when the Ethiopian Government has planned a three-year strategy for the implementation of integrated soil and water conservation activities. The manual has been designed in such a way that important steps can be followed by the community members involved, beginning with identification and analysis of the erosion problem up to its control and impact assessment by applying farmer-expert joint learning approaches and using local erosion indicators.

The manual contains six sections. The first section discusses the background of soil erosion and soil and water conservation. The second section provides farmers' participatory procedures and the methods followed in assessing erosion indicators and existing soil conservation measures. The third and fourth sections cover the description and measurement of local erosion indicators and assessment of the soil and water conservation measures. The fifth section presents the soil and water conservation improvement practices and innovations implemented by the participating farmers in the case study areas. The final section offers conclusions and important lessons learned in the case study. The manual has also been translated into Amharic.

Purpose of the Manual

The main purpose of the new approach presented in this manual is to improve existing soil and water conservation measures implemented in the past in a participatory farmer-expert interaction and common learning approach. The participatory process identifies simple soil erosion assessment indicators, and farmer-expert joint decision procedures used to evaluate soil erosion and improve erosion control measures at individual plot and topo-sequence/catchment levels. The manual emphasizes the importance of simplicity and prioritizes the value of incorporating the knowledge and experience of land users through joint farmer-expert interaction rather than empirical methods in order to build trust and common knowledge for action based on self-learning. This approach works by means of consensus building by exploring land users' knowledge about local erosion indicators through periodic field visits and dialogues. The manual is mainly addressed to land users on individual plots and topo-sequence planning units. It is also addressed to development agents and kebele administration bodies who can play a role in facilitating and supporting farmers' participatory processes.

Acknowledgements

This manual has been prepared on the basis of results of the Q505 research project, **“Conceptualizing rill erosion as a tool for planning and evaluating soil conservation in Angereb sub-watershed, Ethiopia: methodological development,”** which was financed by the Centre for Development and Environment (CDE) through the Eastern and Southern Africa Partnership Programme (ESAPP), for which we are very grateful. We are also grateful to Dr. Fentahun Mengistu for his critical review of the manual. We would like to express our deepest gratitude to the farmers in the study area who actively participated in the process and contributed innovative ideas, and who allowed us to carry out different measurements on their crop fields. Special thanks also go to the development agents and kebele administration in the study sites who played a facilitating role in motivating, organizing and following up on the participatory process. We want also to extend our gratitude to the Amhara Region Agricultural Research Institute (ARARI) for the support given in the administration of the project.

1 Introduction to Soil Erosion Assessment and Soil Conservation Planning

1.1 Introduction

Failure to balance land management interventions with the current extent of land degradation is a growing challenge to small-holder farmers on the hillslopes, in terms of meeting immediate economic objectives and providing sustainable environmental services. Many land-users, though well aware of the negative effects of erosion and other forms of land degradation, cannot afford the labour and other inputs necessary to properly address these problems because they are in a constant struggle for survival. Therefore, strengthening their effort through technical support in building their skill and knowledge about soil erosion and innovative erosion control practices, along with genuine participatory approaches, is essential and must be increased. In the highlands of Amhara region in general, and the case study area in Angereb watershed particularly, where small-scale cereal-based farming systems prevail, there is increased pressure on land use which has resulted in severe land degradation. Soil erosion in association with inappropriate land management practices and minimal adoption of improved soil conservation measures are the main factors causing land degradation. Poor land and water management practices and lack of effective planning and implementation approaches for soil conservation are also responsible for accelerating degradation on agricultural lands and siltation of lakes and reservoirs downstream. Farmers do not make soil erosion a top priority until it reaches the stage of gully formation on their farmland. Most soil and water conservation planning approaches therefore rely on empirical assessment methods by experts and give little consideration to sharing and enhancing farmers' local knowledge about soil erosion in order to improve soil conservation and its implementation.

Past soil and water conservation technology developments have primarily focused on aspects of technical feasibility and use. Past approaches to and experiences with land conservation have led to a lack of awareness and responsibility. Implementation strategies have also contributed to farmers' dependency on soil and water conservation extension programs. A sense of dependency has become a serious problem, particularly in areas where Soil and Water Conservation (SWC) programs using Food-for-Work started early, as well as currently in Safety Net Program target woredas and kebeles. In view of this problem, farmers must be convinced of the consequences of a sense of dependency and lack of environmental awareness, and be motivated to bring about change on their own.

Farming system practices based on social and ecological principles could do more to protect natural resources. Therefore, lessons learned from past soil conservation technology development are such that soil erosion control practices must be planned together with the farm communities that share the catchment and be based on knowledge of local practices. The degree of public awareness of natural resources and its degradation is of crucial importance. In order to reverse the trend of increasing environmental damage and degradation and move towards rehabilitation and improved land management, there is a need to increase public awareness and create options for environmentally and socially

friendly actions. Government institutions can create enabling policy environments that allow local communities to participate in catchment-scale planning and implementation processes. Understanding land and water degradation processes begins with an assessment of individual farm management practices and ends with landscape or catchment-scale management systems following the hydrological units. In many environments, therefore, there is a need to encourage catchment and/or topo-sequence land management options and systems. This helps to ensure that high-priority sites are treated and that there is agreement on holistic land and water resources management.

Effective soil and water conservation technology development at individual farm and catchment scales requires the use of locally suitable and simple methods of critical field erosion assessments. Furthermore, erosion assessment as well as soil conservation planning and implementation ought to be undertaken in participatory processes involving farmers to enhance sustainable adoption of introduced soil conservation measures. Exploring farmers' knowledge of on-site erosion indicators and soil conservation adoption barriers can be useful in assessing erosion risk and improving the efficiency of soil conservation. This process involves frequent field visits and discussions by farmers and farmer-expert joint learning. Eventually, broad-scale adoption of farmer-expert joint learning and application of farmers' erosion indicators for evaluating soil erosion and improving the efficiency of soil conservation measures can be taken as a rational approach in which land users undertake self-evaluation and implementation on their own land. The central idea of the present approach is thus to improve the efficiency of soil conservation through farmer-expert joint learning and application of erosion indicators identified by farmers by involving and empowering them.

1.2 State of soil erosion and soil conservation in Angereb watershed

The case study on which this manual is based is located in Lake Tana basin in Angereb watershed. The area is characterized as mountainous with slopes ranging from 15–60%. As in the other parts of the highlands, land use is predominantly cereal-pulse-based annual cropping mixed with livestock farming. The annual rainfall is described as high and intense with temporal and spatial variations. This high-intensity rainfall in association with steep slopes, frequent tillage practices and shallow soil depth led to severe soil erosion in the area. Soil degradation is becoming a common symptom on most of the steep slopes in the form of gullies, rock-outcrops, depleted soil surface, and low crop and pasture yields. Further evidence of the effects of soil erosion on crop production were observed in the form of sediment accumulation behind field boundaries immediately after seed bed preparation and during the early cropping season. The farmers in the case study area described the impacts of soil erosion on long-term production trends and in terms of environmental damage. For instance, extreme erosion events have occurred since 1986/87 in the form of gullies, damage to bridges, and loss of animals and trees felled by flooding. Farmers also realize the relative magnitude of soil erosion on different crop cover and cultivation practices. These farmers' local crop cultivation and management practices aggravate soil erosion depending on the time of cultivation, crop cover conditions, and management of associated practices such as frequency of tillage and animal trampling.

Table 1 Soil erosion impact indicators (as seen by farmers)

Indicator	Measurement of indicator
Direct erosion impacts	Topsoil surface erosion and gully formation, loss of animals, fallen trees, damage to terraces
Sediment storage capacity of newly constructed terraces	Terrace sediment storage area is filled within 1–3 years or 2–5 years
Soil depth	20–50 cm
Crop yield reduction	Yield reduction on top part of terrace area
Crop cultivation systems	Order of susceptibility to soil erosion: Teff>Barley>Wheat>Faba bean>Fallow
Abandoned crop types	Some barley landraces, field pea, rye, noug and sorghum bicolor
Potential of the land without fertilizer application	Will serve only for the next 2 years without fallow and 2–4 years with fallow (not more than 5 years)

Soil and water conservation measures have been gradually introduced in Angereb watershed since 1977 (Hans Hurni, personal communication). Large-scale maintenance and reconstruction were carried out later in 1993, aimed at reducing sedimentation of the reservoir. At the moment, stone terraces are in widespread use and distributed over the cultivated plots in the study catchments. But no farmers support physical soil conservation structures combined with biological ones, except when the local shrub known as *embacho* is left growing naturally along the terrace structures. It can be said that individual farm plots (an average area of 0.33 ha) have at least one and a maximum of eight stone terraces or soil bunds, though their effectiveness is questionable. The physical conservation measures are characterized by very little storage capacity, damage to structures due to runoff, overtopping the terraces and tillage underneath the terrace structures, unstable terrace cross-section on steep slopes, and unnecessarily wide spacing between successive terraces. There is no common and standard terrace layout and design for the same slope and soil conditions. As a result, fragmented terraces are a common cause of on-site and off-site erosion damage. Because the foot of the terrace structure is tilled every season, the structures in many cases collapse on steep slopes (slope gradient of more than 30%). Inadequate design in the cross-section of stone terraces has led to overtopping of runoff and instability of terrace structures on steep slopes and made them liable to mechanical damage by animals. Soil erosion is further aggravated by improper traditional ditches and cutoff drains.

1.3 Guidelines for soil and water conservation

There are few guidelines in Ethiopia for soil and water conservation and soil erosion assessment. It is thus relevant to present a short review of these guidelines.

1.3.1 Assessment of Current Erosion Damage (ACED) by Karl Herweg (1996)

Assessment of current erosion damage (ACED) is a method designed for monitoring and assessing soil erosion damage of recent origin. It is a field erosion assessment method that can be used to estimate soil losses from current rills and gully erosion, to identify causes of erosion, and to elaborate initial steps in SWC.

ACED has the following merits:

- It is used to estimate order of magnitude of soil losses due to rill and gully erosion, which are usually difficult to estimate by empirical models
- It is used as a tool for monitoring erosion damage (partially) over a longer period of time
- It is used to learn about the factors and reasons that cause erosion damage
- It is a simple assessment method to determine the distribution of severe erosion on the field and can easily be applied by extension agents

ACED has the following limitations:

- It is an erosion assessment method designed for researchers and experts that does not involve farmers in the assessment procedure
- It does not take account of other important farmers' erosion indicators that help to assess the overall land degradation situation. There is no elaboration of how it could be applied at the landscape or catchment level. It is limited to upslope and downslope areas of the field under assessment,
- It is not fully adequate for describing how to control rill erosion damage and development or as a tool for planning soil conservation

1.3.2 Guidelines for Development Agents on Soil Conservation in Ethiopia by Hans Hurni (1986)

These guidelines are designed to serve as implementation guidelines for development agents concerned with soil and water conservation extension. They describe layout and design specifications as well as selection of soil conservation measures for different agro-ecologies and land uses. The guidelines are limited in order to provide locally specific design and layout specifications for soil and water conservation measures. They apply design and layout specifications of soil and water conservation measures to different conditions. For instance, the vertical interval is designed for two slope classes: less than 15% and greater than 15%. For slopes less than 15%, the vertical interval is determined as 1 m, with a terrace spacing exceeding 7 m, regardless of soil depth and soil erodibility. On the other hand, for slope gradients greater than 15%, the interval is calculated in relation to soil depth (equal to 2.5 times soil depth). However, this relationship is neither acceptable nor applicable for implementation of soil and water conservation measures by farmers under existing cereal farming system on shallow soils (in some cases 30 cm on average) and on steep slopes. Unless there is a change in the farming system to fruit based hillslope farming.

1.3.3 Community-based participatory watershed development (MOARD, 2005)

These guidelines aim to provide development agents (DAs) and rural communities with a workable and adaptable planning tool at watershed scale. They also provide practical guidance on the correct selection of technologies under different conditions. They describe the steps to be followed in the participatory processes and interventions and technologies to be implemented, including the monitoring and evaluation stage. They provide

a full package of technical information about intervention technologies. Several participatory approaches are adopted to manage natural resources at watershed scale. However, due to large-scale planning units efforts have remained unsatisfactory as a result of lack of genuine and effective community participation and a limited sense of responsibility. The inadequacy observed in the participatory approach at watershed scale is related to scale and focus. With large-scale planning and implementation, there is less focus on meeting the requirements of smaller planning units, which are otherwise useful for integrated management of natural resources. The participation process also fails to include practically oriented knowledge and sharing of experience among land users that aims to enhance the ecological awareness of land users and build participatory decision systems for sustainable land management.

1.3.4 Gaps and issues to be addressed

Available guidelines exhibit a lack of integration of the local knowledge of land users with the technical solutions for better transfer, adaptation and improvement of soil conservation technologies that fit with the local farming and socio-economic system. They are inadequate for giving full consideration to social aspects in connection with individual land management practices and the knowledge of technology users to understand and transfer the introduced technologies. The guidelines mainly describe technical aspects of land and water management technologies. Locally suitable technologies should be selected and transferred after adaptation and modification of introduced technologies, with the consultation of the land users. The guidelines are often addressed to development agents. For instance, ACED overlooked the capacity of land users during the assessment of current erosion. Therefore, there is a need to build on local knowledge and experience for both erosion problem assessment and soil and water conservation planning. Participatory approaches which enhance farmers' primary leadership of the process and promote the use of a combination of local indicators are comprehensive enough, in terms of both biophysical and human dimensions, to design socially acceptable and physically feasible erosion control measures. This manual thus tries to fill some of the gaps in the existing guidelines, presenting a participatory and joint learning approach – in which the participating land users are involved – by describing individual land and communal landscape erosion problems using their own indicators, as well as related causes and impacts and their local perceptions of erosion, through group field visits and discussions. In addition, practical solutions that fit with production systems and are simultaneously tested for their effectiveness over time are planned and implemented by the farmers themselves.

2 Farmers' Participatory Soil Erosion Assessment and Soil Conservation Improvement

2.1 Concepts and the need for a participatory approach by farmers

An appraisal of different soil conservation technologies must take into account not only the technological means involved but also the approaches that are intended to facilitate successful implementation and adaptation of technologies. In order to enhance action-oriented research and development, continuous assessment and analysis of local land management practices, and related social, economical and environmental factors are important. Thus, there is a need for understanding of specific land resource degradation factors and indicators, farmers' decision-making capacity, and the nature of farmers' responses to the respective indicators in order to plan erosion control options. Introducing ecological thinking and instruments for natural resource management to land users can increase the chances of success in promoting new technologies while also increasing awareness and ecological sustainability. In evaluating problems, stakeholders such as farmers must be invited to take part in a broad participatory process to understand and analyze problems and express and evaluate their needs, interests and aims. On the other hand, land management practitioners must first listen and learn; secondly, they must choose and match what they have to offer – technologies or professional advice – with people's socio-economic needs. Finally, they must monitor and evaluate what happens.

Thus, participatory research and development activities must:

- Empower local communities in their research and development capacities;
- Promote a more participatory and incremental approach to interventions;
- Support analytical tools used to understand social and economic conditions

2.2 Benefits of the participatory approach

Building on the lessons of past soil and water conservation extension, the current approach emphasizes the participation of land users in the assessment of erosion processes, causes, and impacts and in planning effective soil and water conservation practices. It has been identified as a key factor in bringing about positive changes in sustainable natural resources management.

The benefits of the farmers' participatory erosion assessment and soil conservation improvement approach are:

- It provides an opportunity for integrating technical solutions with farmers' preferences. Such an approach is therefore expected to facilitate the acceptance, transfer and application of technical findings and recommendations. This way, farmers are likely to be persuaded to adapt and/or implement conservation technologies without external enforcement.
- The approach acts as a focal point for sharing lessons learned and innovations in practicing community participation, as a means of adding value and empowerment to community environmental knowledge and improving bottom-up communication.
- It empowers communities through demand-driven and user-friendly applications.
- It links farmers' views and knowledge to field erosion indicators to facilitate farmer-participatory erosion research, evaluation, and soil conservation planning and implementation.
- It uses consensus building to develop practical solutions to identify erosion constraints.
- It undertakes participatory assessments of local indicators of seasonal erosion processes and is useful for providing farmers with early warning of unobservable changes such as long-term soil depletion before it leads to more serious and visible forms of soil degradation.
- It is effective in developing improved methods and innovations for sustainable agriculture and assisting decision-makers at farm and landscape scales.

Most importantly, it helps to minimize farmers' sense of dependency in conserving their land.

2.3 Objectives of the new approach

The aim of applying farmer participatory and farmer-expert joint learning approach is to improve the efficiency of existing soil conservation measures and enhance its adoption. The intermediate objective is to establish processes and procedures for developing a participatory methodological approach in order to:

- Assess and identify local indicators and causes of soil erosion,
- Evaluate the potentials and limitations of existing soil conservation measures,
- Facilitate the use of local knowledge about and experience with soil erosion processes,
- Enhance the decision-making process and identify economically and ecologically feasible controlling options
- This will make it possible to achieve the field-level ecological and economic objectives of individual farmers.

2.4 Procedures for soil erosion assessment and soil conservation improvements

The Farmers' Participatory Erosion Assessment and Soil Conservation Improvement (FPEASCI) approach involves the use of farmers' knowledge base and farmer-expert joint learning for soil and water conservation improvement, adoption and extension. The procedure is designed to integrate the knowledge, attitudes and preferences of farmers on the one hand and the local erosion indicators and causes that limit the efficiency of the technology on the other hand. It is based on assessment of local erosion indicators (ALEI) as a tool for soil erosion assessment and soil conservation improvement. The participa-

tory process is developed through facilitating farmer consensus; for example, about which soil erosion indicators on individual fields were most important and what improvements to existing conservation practices and potential erosion control options could be used. Building trust and supporting the local capacity of farmers for consensus building are critical steps prior to collective action by farming communities, resulting in the adoption of integrated soil and water conservation strategies at the field and catchment scales.

The approach involves the following methodological strategies:

- **Self-confidence-building measures:** this is related to awareness and attitude change activities to motivate farmers to engage in genuine participation and build trust. Self-confidence-building measures are carried out in the form of questions and answers.
- **Group formation and participation of land users:** participation is such that all farmers are involved in the key collective decision-making processes. In addition, farmers' research teams can be organized to participate actively and engage in decision-making throughout the processes if it is difficult and unmanageable to involve all farmers. In both cases farmers are active leaders of the participation process. The extension agents and researchers play a role in facilitating motivation and exchange of knowledge. Moreover, kebele administration bodies help to facilitate and organize farmers' interests.
- **Practically oriented knowledge sharing and upgrading:** farmers are involved in exploring their practical experience and knowledge about field erosion indicators, causes and impacts through periodic meetings, field visits and subsequent discussions; monitoring and measuring erosion processes; and evaluating control measures. All land users should be involved in one-to-one and group visits, discussions, and implementation activities on their own and adjacent farmlands.
- **Integrating assessment of field and topo-sequence units**

In smallholder farming systems decision-making begins on the individual farm. The starting point for planning is thus the individual farmer and groups of farmers upslope and downslope from his plot. Thus, focusing on the integration of field and topo-sequence is a major tool in the erosion assessment and conservation planning process. Understanding land and water degradation processes begins with an assessment at the individual farm level and ends with the catchments following the flow of water. Assessments at field scale begin to evaluate the relative susceptibility of individual farmers' soil and crop management practices and to identify the sources of erosion. Assessments of erosion indicators, causes, impacts and performance of conservation measures are carried out by individuals and groups of farmers through periodic visits and discussions in order to reach consensus. Group formation is such that those farmers who own land along the topo-sequence are categorized in the same group in order to create enabling conditions for discussion of their common problems and analysis of the cause-impact relationships of upslope and downslope sources of erosion. The objectives of integrating field and topo-sequence assessment are therefore:

- To gain an understanding of the interrelations of the process-cause-impact sequence of erosion
- To identify a collective understanding of constraints

- To facilitate land users or community linkages in the landscape
- To create a sense of responsibility in conjunction with manageable planning units (farm and landscape)
- To develop a participatory development program

The following procedures are employed to explore farmers' knowledge and increase their awareness of practically oriented soil erosion assessment and conservation improvement

- Community awareness meetings;
- Field visits and discussions to explore erosion indicators, causes and impacts and its measurements;
- Identifying erosion problems and planning potential conservation measures and improvements;
- Implementing improved measures;
- Monitoring and evaluating the performance of implemented measures through direct measurement of sediments trapped and rough nutrient loss.

Individual and group field visits and discussions involve the following steps:

1. Identifying and recording sources (causes) of erosion: runoff source areas, crop tillage management, slope and slope length, poor conservation structures, land use;
2. Assessing and identifying on-site soil erosion indicators and causes: sheet flow lines, rill channels, gullies, surface wash, sediment deposits, ditch erosion, tillage erosion;
3. Identifying off-site erosion processes and causes: gullies, landsliding, sedimentation on field boundaries, etc.;
4. Evaluation of the magnitude of damage on-site and off-site (adjacent farms) by individual farm owners and by groups of farm owners along the topo-sequence;
5. Evaluating the impacts of on-site and off-site erosion processes: physical soil loss, soil depletion, yield reduction, low infiltration capacity, etc.;
6. Corresponding to the sources and indicators of erosion, identifying suitable and cost-effective technologies and assessing points of improvement on existing conservation structures at both field and landscape levels;
7. Screening practices with a view to preventing conflicts among adjacent farm owners involving integrated runoff water management and erosion control principles;
8. Monitoring and evaluating the effectiveness of implemented erosion control measures/practices and identifying further improvements with respect to controlling erosion and preventing conflicts among adjacent farm owners.

If all land users agree, when the number of participating farmers is too large to manage, periodic field visits to assess erosion and improve measures can be carried out by an assigned team of farmers (who have good experience and judgment). However, the results of assessment and planning must be discussed by all land users to reach consensus on collective and acceptable actions. The procedures mentioned are implemented by the group of farmers for every heavy rainstorm and every season, under the supervision and follow-up of local development agents. At the outset, local development agents and researchers play a major role in organizing and facilitating field assessment and monitoring processes until the farmers gain a sense of responsibility.

3 Assessment and Measurement of Erosion Indicators

3.1 Application of erosion indicators

Local erosion indicators are those that farmers can easily perceive on their plots and are suitable for seasonal monitoring of erosion risk and conservation measures. By visualizing the spatial distribution and development of erosion processes on both terraced and un-terraced fields, farmers can easily observe erosion damage and the limitations of terracing and also envision where to plan conservation measures. Visualizing the development and distribution of erosion processes, causes and impacts over the toposequence is thus a concept to be taught and shared among farmers for purposes of erosion evaluation and soil conservation improvement. On periodic visits to individual plots and the catchment, farmers identify erosion indicators that can be used to show the magnitude of erosion hazards. Assessment of Local Erosion Indicators (ALEI) is therefore meant not only for assessment of erosion risk but also for evaluating the design and layout (vertical interval, spacing and cross sections) as well as the efficiency of integrated soil conservation measures. Several different measurable erosion indicators provide evidence of erosion hazards and their impact. Simple and combined indicators where many of the measurements can only be easily described and understood by farmers are very useful. Erosion indicators are applied differently as follows:

- To provide evidence of and determine the magnitude of erosion at individual field and catchment scales,
- To show both the process and the likely cause of land degradation through time,
- To evaluate existing soil conservation measures and identify improvements,
- To determine the spacing and/or vertical interval between terrace structures under different conditions,
- To bring individual indicators together for comparative and overall assessment, including how to develop a procedure for getting an overall picture to assess and evaluate erosion and to improve soil and water conservation.

Commonly known local erosion indicators identified by farmers on cultivated fields are:

- Exposure of crop roots on the surface; variation in crop growth and yield following the slope gradient; reduction in pasture yield for feeding animals, etc.;
- Change in the cropping pattern; Minimal soil depth and evidence of outcrops; change in soil texture to gravel or rock fragments;
- Surface soil wash and rill channels with depths of > 5 cm;
- Gullies, landsliding and flooding;
- Sediment deposition behind conservation structures and plot boundaries;
- Bed erosion on traditional ditches; sediment deposition and gullying at the outlet of the drain;
- Decrease in the soil surface level surrounding big stones and tree mounds;
- Tillage erosion, and
- Loss of bushes, shrubs, and trees

3.2 Description and measurement of erosion indicators

Rill erosion

Description: rills are used to describe small forms of linear erosion caused by overland flow. Rills are visible and noticeable linear erosion features easily identifiable by farmers (Herweg, 1996). Among other indicators on agricultural lands, rill erosion (defined by a depth > 5 cm according to farmers' assessments) is one that farmers can easily perceive on their plots and a suitable indicator for seasonal monitoring of erosion and identifying the limitations of conservation measures. Moreover, it occurs every year and is more widely distributed over cultivated fields than other indicators, whose occurrence and distribution is limited to specific spot areas. As a result of its formation, rill erosion leads to significant erosion damage without being noticed by farmers. This indicator is directly adapted from ACED (Herweg, 1996) with a particular focus not only on erosion evaluation but also on soil conservation planning and improvement. Thus, it is a commendable tool for practical conservation-oriented assessment of soil erosion. Combining rill erosion assessment with a farmer-expert joint learning approach, offers an effective basis for soil conservation measures.

Measurement of indicators: the land users visit their fields during subsequent tillage periods and after planting to identify overland flow channels and determine the formation of rills. Once rill formation is identified, rill numbers, rill depth, rill width, rill starting distance away from upper terrace structure and its development are the means of measurement for indicators of the magnitude and distribution of rill erosion. Based on the measurements, farmers decide the risk of on-site and off-site erosion in order to improve and implement anti-rill erosion measures.



Figure 1 Formation and development of rill erosion on the area between terraces

Sediment accumulation behind terraces and check dams

Description: accumulations of sediment behind terraces and check dams are a useful indicator that soil movement has taken place in the field, and that, if it were not for the terrace and check dam, soil would have been lost beyond. An example is shown in Figure 2a and 2b, where the sediment trapped by the terrace and check dams risers constructed can be measured to make an assessment of the minimum amount of soil that has been lost from the upslope areas. The assumption here is that the sediment material retained on the structures has been eroded from the upslope area due to improper land use, steep slope gradient, damaged terraces, and/or other poorly functioning practices. Based on data from the case studies, the initial storage capacity of terraces on the field is silted up within 1–5 years, depending on sources of sediment, the slope of the field, and terrace spacing and its design storage area. Most of the terrace capacity is silted in one season, and in very limited cases high seasonal accumulation of sediment is measured on some well-constructed terraces. However, it is useful to view the apparently eroded soil through the eyes of the farmer because:

- After a few seasons, the soil close to the terrace is relatively rich in organic matter as well as deep, with high soil water content; hence the crop yield is comparatively high;
- Meanwhile, farmers harvest grasses along the structure to feed their animals;
- After some years, when the terrace has filled with sediment, the farmer may cultivate the accumulation area and may also remove the old terrace and plant crops in the accumulated rich soil;



Figure 2a Sediment accumulation behind soil bund structures

Means of measurement: seasonal sediment accumulation behind terraces can be estimated with reference to the initial basin capacity. Measure the change in the accumulated depth of sediment using well distributed wooden pegs (graduated) covering the basin

area constructed initially. At the same time, measure the sample basin area (width by length) in order to obtain the total volume of sediment stored behind terraces for a given time.

Tillage erosion

Description: soil is washed down naturally by rain but most erosion is what is referred to as 'plough erosion', that is, soil moved downslope by the action of cultivation. On steeper slopes, the soil is gradually washed down due to translocation by tillage implements every year. According to Nyssen et al. (2000), tillage translocation accounts for half of the sediment accumulation behind newly constructed stone bunds. On slopes steeper than 15%, all soil is thrown to the lower side of the tillage furrow (Nyssen, et al, 2000). A typical indicator of tillage erosion is clearly observed beneath the terrace structure, where the soil surface is significantly lower than the foundation of the terrace. This means that there is a situation where erosion has been unnoticeably 'encouraged' by the farmer's practices. Farmers are less aware of this and may not consider soil movement resulting from tillage practices as a soil erosion problem.



Figure 2b Sediment accumulation behind stone check dams for different storm events

Means of measurement: A simple form of assessing erosion resulting from tillage translocation can be carried out systematically by measuring the change in the soil surface depth, before the start of seasonal rainfall, with reference to the stone terrace base and other permanent reference objects, such as big stones, before and after tillage preparation. Monitoring the displacement of selected small stones or gravel downslope is another method of quantifying soil movement by tillage.



Figure 3 Evidence of tillage erosion underneath stone terrace structures

Erosion from traditional ditches

Description: Construction of traditional drainage ditches across the slope is a common practice of farmers to protect the lower field from concentrated runoff during heavy storms. Most of the farmers construct drainage ditches every year randomly on the plot, with irregular spacing. The magnitude of erosion from ditches depends on how well or how poorly a farmer's ditches are oriented. In most cases, the ditches are constructed with gradients significant enough to cause erosion, sometimes even up- and downslope. Obviously, sediment transport along ditches and soil eroded from ditches are accumulated downslope. There is also sediment that has apparently been washed completely out of the field. Sometimes the runoff discharged from ditches damages terrace structures and creates gullies downslope. The accumulated sediment at the outlet of ditches and the development of ditch cross-sections are common indicators of erosion in the field.



Figure 4 Runoff erosion and sediment lost from traditional ditches on farmers' plots

Means of measurement: The contribution of ditch practices to erosion damage is estimated from:

- Changes in the cross-section (depth and width) of ditches after preparation by recording development periodically or after every heavy rainstorm;
- Accumulated sediment at the outlet, by measuring the change in soil surface using graduated wooden pegs,
- Rills and gullies observed at the outlet, either within the field or after crossing several farmers' fields

Yield reduction and variation in crop growth

Description: Farmers commonly experience variation in crop growth and yield reduction on their farms. Crop yield reduction and variation in growth are the erosion indicators most frequently listed by farmers to explain the problem of local erosion impact. In the case study, crop production monitoring in the inter- and intra-terrace area clearly indicates yield reduction along the slope length. Extreme erosion damage on shallow root crops exposes the roots to the surface, making it easy for land users to perceive and be aware of the first stage of erosion. Erosion causes significant on-field variation in crop-growth conditions, with the upper parts generally producing the poorest crops. At the top of the field, crop stands appear stunted and yellow-looking. Towards the lower and middle parts of the field, some of the plants have a purplish colour on new leaves, whereas plants growing in the sediment accumulation along the field boundary and behind terrace struc-

tures are vigorous and deep green in colour. Farmers in the case study area responded that they have experienced up to 5–7 % annual yield reduction on erosion-prone fields.

Means of measurement: variation in crop growth conditions and yield is monitored during seasonal field visits. Farmers try to sample and compare separate crop harvests from upper, middle- and lower open terrace areas or from different inter- and intra-terrace areas so that the economic impact of erosion on crop productivity (yield and biomass) can be quantified.

Change in the cropping system

Changing the cropping system is another local indicator that can show the effects of soil degradation. In the study, it was found that several barley landraces with better productivity were abandoned in the production system as the result of changes in the soil function. Among many of the locally named barley landraces in the case study area, for instance, *Temej*, *Awura gebes*, *Worehimen*, and other crops such as rye, sorghum bicolor, finger millet and in some cases field pea can be mentioned in this regard. On the other hand, crops such as lentil and fenugreek have been adapted to degraded and depleted soils.

Shallow soil depth and change in soil texture: reddish, gravel or rock fragments

Description: farmers are worried about parts of their fields becoming lighter and sandier. They try to cope with soil depletion problems by growing crops that adapt to shallow soils and soils with rock fragments, such as lentil, fenugreek, and sometimes allot the field to pasture production. Nonetheless, though farmers are aware of the problem, they are struggling to produce food on this part of the land. However, simple analysis of the costs and benefits suggests the need to change the production system to profitable land resource management options such as forage legume production and timber production.

Means of measurement: soil depth is commonly observed and monitored during ploughing. Farmers can easily describe soil depth in terms of ploughing depth. Almost all cultivated fields in the case study areas with slopes greater than 15% have soil depths less than ploughing depths. Soil depth is gradually diminishing, averaging between 5 and 100 cm. Most cultivated fields with very shallow soils of less than 20 cm have changed to gravel texture and are reddish yellow in colour.

Tree mounds and exposure of tree roots

Several trees have been left on and around agricultural fields. Tree mounds are apparent, indicating that the surface of the soil on the field has become thinner, presumably because topsoil has been washed off since the field was opened for cultivation. Sample field assessments in the case study areas determined that mounds ranged from 20–170 cm in height above the surrounding soil surface, clearly indicating long-term soil degradation processes caused by tillage and water erosion. The longer-term effects of degradation processes result in the exposure of the deep root systems of trees, an obviously good indicator of local erosion. Absence of several indigenous tree and shrub species and the existence of newly adapted shrubs is another indicator of the changing environment.

Means of measurement: regular monitoring of soil surface levels surrounding permanent trees and soil heaps can be done using local measuring tools to show the long-term

effects of erosion. Recording extinct trees and shrubs as well as newly adapted shrubs is another means of monitoring the impacts of erosion and land degradation.

Permanent stone mounds

Farmers have gained good experience and developed knowledge of field erosion by identifying the changes in the soil surface level around big stones on their parcels. These types of indicators provide evidence for the parts of the field most exposed to water erosion.

Means of measurement: farm owners and adjacent landowners can be asked to recall the historical development of changes in the soil surface surrounding big stones on their fields and in the landscape. Taking farmers' responses as a reference, a few sample measurements can be made for estimation. In addition, additional sample measurements of the difference in height between the ground surface and stone mounds provided evidence of long-term field erosion.

Abandoned or fallow lands

Due to long-term farming and continuous cultivation in association with excessive soil erosion, soils are depleted and unable to produce subsistence yields. Consequently, farmers practice long-term fallowing or abandon plots used for production.

Gullies and landslides

Farmers are very aware of land degradation when they observe gullies and landslides, though they have less capacity to mitigate these forms of erosion. In this case, external assistance and catchment-level soil conservation planning is needed



Figure 5 Active gully damage and associated landsliding

In conclusion, case studies on semi-quantitative assessment of local erosion indicators with the full participation of farmers indicated that while farmers are aware of highly visible gully erosion, they were less aware of more dangerous seasonal indicators such as sheet erosion, rill erosion, ditch erosion, and tillage erosion. They do not perceive the long-term and irreversible consequences of seasonal erosion processes. While seasonal indicators can be controlled affordably, gullies, landsliding, yield reduction, flooding, soil depletion, loss of trees, pasture yield reduction to feed animals, etc., are noticed easily by farmers but are costly and beyond their capacity to reverse and control. In addition to common indicators, historical development of erosion can be manifested by the change in soil surface levels around trees and big stones, traditional bunds left inside cultivated plots, and tillage erosion apparently observed underneath the terraces. The cause and effect relationship of these erosion indicators is the most important lesson to be learned by farmers. While each indicator has its own attributes and applications, piecing several indicators together can present a far more comprehensive and consistent picture. Such methods of field-based erosion indicator assessment and identification of indicators by farmers through visits accompanied by measurements are good examples of how to increase awareness and skill and motivate farmers to protect and control field erosion.

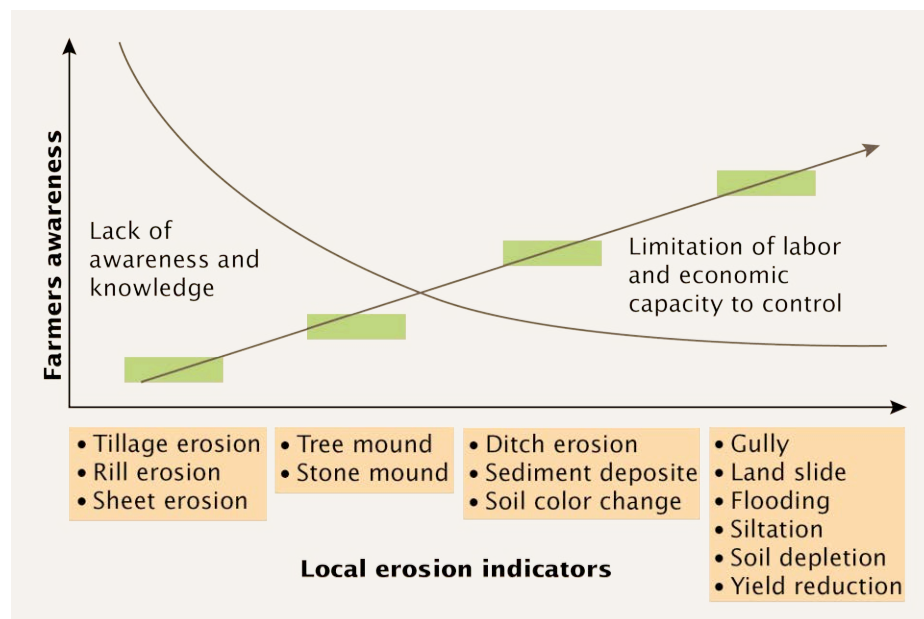


Figure 6 Diagram showing farmers' level of awareness for different local erosion indicators

4 Assessment of Soil and Water Conservation Measures

On slope gradients greater than 30%, where simple vegetative control measures and agronomic practices alone are not effective in controlling erosion, stone terraces or soil bunds are necessary. The most commonly practiced mechanical conservation measures are introduced stone terraces, traditional ditches, and cutoff drains.

4.1 Performance of stone terraces

In the highland areas, stone terraces are widely distributed on all farm plots. Terracing requires labour and capital investment and causes some inconvenience to farmers. Terrace abandonment, improper terrace layout and cross-sections, and lack of maintenance are often observed on agricultural land. In order to quantify technological performance, assessment of the stone terraces was carried out from both the technical and the farmer's point of view. Technical assessments are predominantly based on scientific evaluation of the characteristics of the conservation measures, while farmers' assessments are usually done in the context of the farming system and express social and cultural interests and preferences. As a result, the assessments and evaluations of these actors will definitely employ different sets of measurements and indicators, with some in common.

4.1.1 Technical assessment

The objective of terracing is to retain soil in its original location, thereby reducing soil loss downslope. This can be achieved by depositing washed out soil particles in the area between terrace structures so that a bench is formed. Assessing the effectiveness of stone terraces can therefore be done from the point of view of layout and design as well as ecological sustainability. The design of a terrace involves the proper spacing and location of terraces, the design of a channel with adequate capacity, and development of a formable cross-section. Spacing of a terrace is expressed as the vertical distance between successive terraces. Terrace spacing should not be so wide as to cause excessive rilling and resultant movement of large amounts of soil into the terrace channel. The runoff from the terraced area should not cause overtopping of the terrace, and the infiltration rate in the channel should be sufficiently high to prevent severe damage. Therefore, the effectiveness of terraces is technically evaluated in terms of storage capacity, the cross-section of the terrace, and terrace spacing.

Storage capacity of terraces

Comprehensive assessment of all terrace structures in the case-study catchments showed that the storage capacity is reduced on steeper slopes. The structures are filled up and damaged due to runoff overtopping the terraces and to tillage practices beneath the terrace. Adequate storage capacity on some terrace structures is mainly the result of lower slope terrace position and the relatively flat segment of the plot that retains sediment lost from the terrace area, owing to reduced runoff velocity on the moderate slope section near the terrace structure. Otherwise, in most cases no clearly defined storage channel was observed.

Cross-section of terraces

As one element of terrace design, the cross-section of a terrace is taken as a further indicator in evaluating terrace performance. Inadequate design in the cross-section of terraces leads to the overtopping of runoff from the terrace area, instability of the structures on steep slopes, and liability to mechanical damage by animals during free grazing. Assessments of the riser height and top width of terraces have shown that the existing terraces will not perform their functions unless immediate remedies or improvements are made. Because the foot of the terrace is tilled every season, the terraces are collapsed on most of the terraced fields. Though most stone terraces are often collapsed, the design height is exceeded as a result of terrace base erosion. The cross-sectional area of terraces (height multiplied by width of terraces) is less than the design area indicated in the existing guidelines. In conclusion, the stone terraces in most of the highland areas are not in a stable enough condition to perform their functions properly. Maintenance and improvements under such unstable conditions become difficult. On steep slopes the risers are so steep that it is impossible to add more stones on the top. Hence, either building a reinforcing terrace at the foot of the original terrace or complete removal and re-establishment of a new terrace are possible options for maintenance. Nevertheless, in situations where very high amounts of sediment accumulate on terraces over the years, many farmers do not favour the options of complete removal and shifting the position of terraces.

Terrace spacing

Three slope factors affect erosion, namely steepness, length, and curvature. The steeper the slope, the greater the erosion. The longer the slope, the more erosion there will be. In the design of conservation structures, an account of these topographic factors under various soil, land use and climatic conditions is necessary to achieve proper layout of the structures. The slope length at which overland flow becomes erosive is called critical slope length. Provided the effective slope length can be maintained below this critical value, serious soil erosion will not occur. The technique for reducing slope lengths is to break up the hill slope into segments using terraces. Deciding on suitable spacing for the terraces therefore requires the capacity to correctly estimate the critical slope length. Spacing between terraces is thus taken as an indicator of the effectiveness of terraces. In principle, the spacing should be decreased when the slope increases. The present study has, however, showed the opposite: that an increase in the vertical interval is observed when the slope increases. Likewise, the terrace spacing was very wide (more than 10 m) and created favourable conditions for rill channel formation. In addition to damaged and unstable terrace structures, such wide spacing caused runoff concentration that led to excessive erosion. The combined effect of inappropriate terrace cross-section and spacing has reduced the efficiency of terraces in enhancing crop production on treated agricultural lands. This aggravated on-site erosion behind the structures and caused irreversible degradation downslope, where concentrated runoff broke through fragmented and defective terrace sections and further merged with the traditional ditches. However, despite this problem, farmers do not accept narrow spacing since it considerably reduces the cropping area.

Terrace density

Provided that the proper design and layout specifications are maintained, the performance of terraces can also be judged by the intensity and spatial distribution over the catchment, which can be used to compare and evaluate soil conservation development at

catchment scales. However, terrace density alone does not provide enough information when design and layout characteristics fail. It is therefore important to use a combination of design (cross-section), layout (spacing) and intensity and distribution indicators. Existing terrace density in treated catchments is very low compared to what has been suggested in the design specifications in the implementation guidelines (Hurni, 1986). The small number of terraces per individual field is a result of farmers' complaints about narrow spacing of terraces and reduction of cropping area. However, the area occupied by existing terraces per hectare is less than 0.5 % which results in up to only 10–16 kg ha⁻¹ approximate yield loss for wheat and faba beans. A fair balance has to be maintained between yield loss due to land lost by terrace structures and yield loss by soil erosion in order to maximize the productivity of the land.

4.1.2 Farmers' assessment of terraces

Due to increased population pressure, farmers in the highlands of Ethiopia in general and those in the case study area in particular are facing fragmentation and a shortage of farm plots. The impact of terracing largely reduces soil erosion; but it is difficult to absolutely stop soil erosion. This makes it difficult for farmers to realize the full benefits of conservation. Despite the fact that terraces are good for conserving soil and water, farmers asserted that it is not possible to conclude that soil erosion is fully controlled after their fields are conserved with terraces. At the current level of perception by farmers, the benefits of terracing are seen in terms of immediate economic objectives. For this reason their assessment criteria are mainly related to the effectiveness of terracing, the utility brought about by retained sediment and the expenses incurred for establishment and maintenance. Crop yield benefits, the amount of labour and capital invested, and areas occupied by the terrace structure are assessment indicators commonly mentioned by farmers. Farmers notice crop yield differences year after year and between upper and lower terrace sections. The lower terrace area is more productive than the upper terrace section. The choice of conservation measures is made depending upon the area occupied and the amount of labour required. The points below, often listed as reasons for the failure of conservation measures, are among the assessment indicators usually mentioned by farmers.

- High labour for construction and maintenance,
- Considerable area occupied by terraces,
- Narrow spacing for farming operations,
- Lack of construction materials

These farmers' indicators are mainly associated with labour, land and capital expenses incurred by the structures. This implies that they give less attention to the ecological feasibility of conservation structures. If a given conservation measure is to be effective, it has to be measured in terms of both economic and ecological indicators.

There is no way that farmers will accept soil conservation measures without a compromise between the technical design and layout specifications and their own interests and knowledge. Through continuous discussions and knowledge sharing at field level, consensus among farmers has to be achieved on the critical cross-sections and critical spacing between terrace structures. Based on rill erosion development between terrace structures, for example, some farmers in the case-study catchments have mentioned a critical terrace spacing of not less than 5 m. From a technical point of view, this critical

spacing is only applicable for all slope classes with soil depths greater than 1m (according to Hurni's (1986) guidelines). For shallow soils there will be limitations on agricultural production in all slope ranges. However, further field-based assessments and thorough and repetitive discussions are needed to establish the critical terrace spacing under different sets of conditions among farmers.

In the same manner, the cross-section (height and width) of terraces has to be evaluated by farmers. In constructing and maintaining terraces, farmers view the cross-section from the angle of stability of construction material and labour availability. Stone terraces are less preferred by farmers mainly because of maintenance and labour costs as well as rodent harbouring problems. The lower preference of farmers for stone terraces provides an option to integrate physical and biological conservation measures, which are more environmentally feasible and economically viable. Gradual accumulation of sediment behind terrace structures can be retained with the support of biological materials because when the sediment accumulates further, plants grow simultaneously. Land occupied by terraces per hectare is an additional indicator. Farmers are often reluctant to built new terraces between existing ones, as they fear that there will be additional land and labour costs due to extensive terracing. This requires continuous discussion with farmers to instil knowledge about the merits of technical considerations in the design and layout of terraces so that they will determine their own decision system from both a socio-economic and an ecological point of view.

4.2 Assessment of traditional ditches and cutoff drains

Small-scale drainage is almost always practiced by farmers who wish to remove surface water from arable fields. The essential principle of any type of drainage is to provide an open, adequate and readily accessible channel through which the surface or subsoil water can flow. For this purpose, open ditches are used in many parts of Ethiopia where water-logging in Vertisols and excess runoff in moderate slope areas occur. In the highlands, some form of artificial network, in addition to the natural streams and channels, drains a very high percentage of the land area. This indigenous drainage practice takes many different forms, from series of broad-bed and furrow (BBF), ridge and furrow (RF) to simple open ditches on flat Vertisol areas and moderately steep areas. The form of drainage present in different areas depends on the problem that is to be alleviated. The primary aim of drainage is to reduce the level of excess soil water in order to improve conditions for cultivation and to remove excess surface and sub-surface runoff for the control of erosion. In this section, the focus is restricted to simple open ditches typical for removal of excess soil water and excess runoff generated by high rainfall before rills develop. This kind of traditional ditch is made by pressing a local plough and by hand, digging deep into the ground.

The density and dimension of the ditches are dependent on the nature of the soil, the slope of the land and the amount of excess soil water and runoff to be removed. This land drainage often involves deep ploughing of the soil at different spatial ranges. It has frequently been ploughed down the main line of the slope with varying gradients. But the minimal depth of these channels and their rapid silting once the rainy season starts make them inadequate; they may also be sites of accelerated erosion. Properly constructed

drainage systems can prevent erosion and gullyng of land on slopes by catching surface water before it reaches the critical stage.

Coarse-textured soils were found to be drained with widely spaced ditches while clay soils were drained with closely spaced ditch systems. Slopes usually dictate the orientation of ditches. On lower slopes ditches are dug along the slopes while on steeper slopes they are dug at an angle to the main slope to assume reduced slopes. However, on some farms the ditch slope was the same as the land slope, which means the ditches were dug along the maximum slope. This may result in facilitating and aggravating erosion by water. The average top width, bottom width and depth of the drainage ditches were in the range of 30–45 cm, 15–22 cm and 13–16 cm, respectively.

In Angereb watershed, except those plots with high stone density, every individual farmer (an average area of 0.33 ha) has constructed at least 3 and at most 9 traditional ditches on the field to safely remove excess runoff. Seasonal monitoring of the traditional ditches in the case-study areas has shown that 6.3, 8.6 and 20 mm changes in the depth of ditches were observed and measured in a one-month period (July to August) at *Godgua-dit*, *Kiltem Sebari* and *Embes Tig* sites, respectively. Similarly, the respective change in the width of ditches was 25.8, 29.0, and 20.8 mm. Other studies in the highlands of North Shewa around Debre Birhan have shown that on cultivated lands with slopes less than 10% and drained by traditional ditches, soil loss was in the range of 20–35 ton-ha⁻¹. The results further showed that ditches, especially during erosive rains, encouraged runoff erosion the extent of which was further aggravated by increasing land and ditch slopes. This implies that the hydrological and erosion potentials/impacts of ditches are considered very high.

On the other hand, cutoff drains with depths greater than 20 cm were made using traditional ploughs or hand tools on the upper border of the farm to protect against floods, using stone and/or soil bunds. These can be temporary (for one season) or permanent when constructed together with adjacent farm owners. Each parcel has cutoff drains along the upper boundary except where there are field boundaries in the form of traditional bunds. The household head constructs these with his family during the rainy season. This practice is very useful for protecting highly concentrated runoff from upper source areas. Unless there is proper construction and communal layout of cutoff drains, there is a high risk of erosion downstream in the form of rills and gullies that can lead to conflicts among adjacent landowners.

The negative impacts of these practices were mainly observed in the formation of gullies downstream that damaged the terrace structures and served as sediment-transporting channels. However, many farmers, though well aware of the negative effects of other forms of erosion and land degradation, do not notice the risk involved with traditional ditches and cutoff drains in properly addressing erosion problems since they are constantly struggling only to control highly recognized and visible forms of erosion.

4.3 Evaluation criteria for the assessment of soil conservation measures

There are several reports that indicate the meagre achievements of past soil conservation efforts and minimal adoption by farmers. Since performance is highly dependent on location and farmers' situations, it is essential to evaluate each and every soil conservation measure using locally developed criteria. Each evaluation criterion results in hierarchical decisions about limitations on design and layout specifications, the efficiency of erosion control in the area between terrace structures, and suitability and fitness for the farming system. The criteria are designed in such a way that they enable farmers to make decisions about the overall performance of each conservation measure and to identify and suggest improvements. On the other hand, in addition to evaluating each conservation measure, the hierarchical decision criteria provide information on strengths and weaknesses in order to identify the best measures in other guidelines. See Annexes C and D for the criteria developed particularly for stone terraces and traditional ditches.

5 Improvements in Soil and Water Conservation Measures

The major focus of the participatory and farmer–expert joint learning and action approach is to motivate farmers and integrate their experiences and attitudes about the processes, causes and impacts of soil erosion in order to improve the effectiveness of soil conservation measures. Once farmers understand and analyze erosion problems at field level and in topo–sequence units, based on local erosion indicators and the limitations of existing soil conservation measures, they are asked to implement improvements that fit with their farming system and are affordable. These improvements are designed to improve wide terrace spacing and unstable terrace cross–sections, and identify causes and indicators of erosion such as rill erosion, ditch erosion, gullies, and others. Terraces can be effective if and only if they are used in combination with other soil and water conservation measures. Through continuous field visits and on–site discussions, land users can explore possible improvement options and new techniques.

5.1 Improvement options

Some successes have been recorded in improving the effectiveness of existing terraces at the case–study sites. However, these improvements were mainly observed on a few farmer plots and require further follow–up in order to scale them up on neighbouring plots and at catchment scales. More interestingly, some innovative farmers established homestead demonstration plots for different soil fertility management measures which will help to motivate adjacent landholders. Lists of improvement options practiced by the farmers are described and illustrated below.

Integrating trenches with terrace structures

Modified trenches (with dimensions modified to fit plot slope and terrace conditions) are constructed to partially retain runoff water and sediment from the terrace area (Fig. 7). This substitutes for graded runoff storage basins or channels. The modified trench improves efficiency of the terrace and provides multiple functions:

- Retention of excess runoff water which otherwise overtops the terrace and causes damage to the structure and to downslope plots;
- Avoidance of sediment loss and off–site damage from excess drainage water from terrace channels on side waterways and adjacent plots;
- Retention of sediment eroded from terrace area;
- An increase in the amount of water that infiltrates through reduction of the overland runoff component;
- An increase in available soil moisture during terminal drought with consequent improvement in the yields of crops cultivated below the terrace structure;
- An increase in interflow and possible long–term improvement in recharging;
- Compost preparation from weeds and other shrub species collected during the cultivation period after the end of the rainy season



Figure 7 Improved terrace structures with runoff water collection trenches

Maximizing the benefit of terraces

Free grazing is a challenge in the face of attempts to promote multi-purpose tree plantation and biological conservation measures on terrace structures. Despite the grazing problem, in addition to local shrubs growing naturally along terrace structures, some farmers are currently adapting value-added plantations such as *tena adam* (Fig. 8), grass pea and weeds for feed that fit into the annual cropping system, and *Ficus thonningii* (*chibha*) tree plantation along terraces.



Figure 8 Improved terrace structures planted with high-value spice plants

Improvements in the top terrace section

Damage to stone terraces due to unstable cross-sections is common. It is also difficult to maintain or improve stone terraces on steep slopes by adding more stones. Improvements are made on the top cross-section of the terrace structure. The height of structures on the upper side is built up to the ground surface, while the lower side riser height is increased to retain maximum sediments. These improvements increase structural sta-

bility and reduce liability to mechanical damage. The inclined top cross-section of the structure is developed through time by adding soil and local vegetation when storage capacity is filled by eroded sediment.



Figure 9 Improvement on the cross-section of terrace structures

Shifting terrace position

Shifting silt accumulated on terraces, mainly downwards and sometimes upwards on small plots at intervals of 4–5 years, is a common improvement practiced by farmers in the highlands. The farmers' reasoning is that the soil deposited on the previous terrace structure is presumed to be fertile in comparison to the soil removed from the structure. Hence crop yields increase when this part of land is planted. However, limitations are observed after a certain period of years. This practice has caused disturbance of already long-deposited soil that forms bench terraces and of soil washed further downslope.



Figure 10 Old terrace structures shifted downslope

Check dam construction along waterways and gullies

Farmers have been constructing check dams on waterways with erosion risk, on foot paths and in gullies. They try to quantify the sediment retained by the check dams after every rainstorm in order to become more aware of soil and nutrient loss from farm plots. Incorporating periodic sediment monitoring is thus an improvement on the practice of building check dams.



Figure 11 Series of check dams constructed along pathways

5.2 Appraisal of catchment-level improvements using new approach

Catchment-level improvements of soil and water conservation are guaranteed as a result of the integration of field and topo-sequence assessments. Part of the new approach is grouping farmers who own land on a topo-sequence. Such group organization makes it possible to identify common erosion sources, to enhance communication among upstream and downstream farm owners, to come up with interventions and improvements and minimize downstream erosion damage as well as avoid conflicts, and to understand erosion-related problems on individual and communal lands.

Erosion indicator assessments on individual fields make it possible to understand dominant erosion factors linked with farmers' decision systems at farm level. Individual decisions related to tillage management, crop cover type, slope length between terrace structures, slope shapes on the field, waterways and ditches, etc. affect on-site and off-site erosion processes and resulting impacts. On the other hand, erosion indicator assessments on the topo-sequence identify more integrated erosion factors linked with community land use and management practices, landscape structures such as a series of terraces, waterways and cutoff drains and field boundaries, topographic features (slope concavity and convexity), and upslope runoff source areas. While each indicator has its own attributes and applications, several indicators in combination can piece together a far more comprehensive and consistent picture of land degradation and subsequent rehabilitation and improvements at catchment level. This is of interest to all individual farmers as well as those at the catchment level in order to achieve common understanding.

This on-site assessment has encouraged the use of different local erosion indicators in combination, preferably with the active input of farmer experience. The integrated field and topo-sequence-based assessments have impacts in terms of changes in the awareness of

farmers, owing to joint planning to avoid conflicts, changes in knowledge and understanding of causal relationships related to characterizing and managing the topo-sequence and/or catchment, and changes in innovative practices for improving existing soil conservation measures. Furthermore, during on-site assessments and the evaluation stage, farmers are encouraged to make partial estimates of the sediment loss and nutrient loss from the catchments that is retained by the constructed check dams and field boundaries during rainstorms and during the season. This inspires them to observe and analyze erosion impacts at catchment level in order to consider interventions beyond their plot. Through the new approach, appraisal of catchment-level improvements is ensured by means of controlling gullies and pathways, improving cutoff drains and traditional ditches that divert runoff to adjacent farmland and cause off-site erosion and conflicts, and avoiding discontinued terrace structures within fields and between adjacent farmlands.

While improving existing soil conservation measures at field and catchment levels, some of the following measures require careful collective and farmer-expert joint decision and due emphasis during the implementation period.

1. Improving old and completely filled stone terraces on steep slopes

- This raises such questions as: If maintenance is carried out at the original location is erosion controlled effectively? Is it not difficult to do continuous maintenance? When a stone terrace is very high, it is liable to damage and the runoff overtopping the structure causes severe erosion at the bottom of the terrace.
- If the terrace structure is removed and shifted upwards or downwards, the accumulated sediments can easily wash away. Thus, it is very important to discuss the advantages and disadvantages of maintaining stone terraces on steep slopes to come up with effective solutions.

2. Constructing cutoff drains

- Cutoff drains are only required when inflow runoff is very high, otherwise it results in severe damage when proper construction is inadequate.
- Where necessary, it is always advisable to integrate and support the cutoff drain with biological conservation measures.
- Cutoff drains are often the main source of conflict between farm owners in the topo-sequence. It is therefore essential to agree on the layout of drains in the presence of all concerned landowners.

3. Constructing new terrace structures

- Terrace spacing is decided with the agreement of the landowner in such a way that rill formation and development is avoided.
- The upper and lower side heights of terraces should not necessarily be equal on steep slopes in order to retain washed sediments due to sheet erosion and to increase structural stability.

- In order to increase the annual sediment storage capacity of terraces as well as to protect erosion damage in downslope areas, it is highly recommended to integrate biological measures and physical structures.

4. Constructing traditional ditches

- The first and foremost advice regarding traditional ditches is to prevent the generation of concentrated runoff on the field. If feasible, replace with non-erosive drain systems and plant with cover crops to control soil erosion on field plots.
- Based on past experience of how the gradient affects runoff concentration and erosion in the ditch system, improve the gradient without causing damage.
- Care must be taken to avoid formation of gullies and terrace damage at the outlet of ditches.

5. Promoting improved land management systems

- As a result of continuous cultivation and erosion problems, most of the marginal lands on steep slopes are degraded and unable to produce subsistence crop yields. It is better to change to other land use systems that benefit the farmer economically and result in sustainable use of natural resources.
- Since tillage frequency is one cause of accelerated erosion, it is advisable to practice minimum tillage techniques and strip cropping and cultivate crops that require less frequent tillage management.

6 Conclusion

Land degradation can be understood in both social and environmental contexts. But as context is so diverse from place to place and time to time, only real local understanding can provide insights into the fundamental issues. There is a general understanding that land degradation in the Ethiopian highlands is related to individual and communal land use and management practices. Therefore the key issue in reversing land degradation trends and in providing insights into potential solutions to land degradation problems is understanding the factors that drive farmers to choose land management practices. The farming system and associated land management practices used in a particular location result from the decisions taken by farmers in the allocation of production factors to production processes to meet household objectives. Thus if erosion problems are to be understood and effective soil conservation measures planned, both the biophysical and human dimensions that characterise direct decision-makers (farmers) need to be considered.

Farmers are constantly subjected to changes beyond their control owing to factors that affect the viability and profitability of the farming enterprise. Therefore, in order to sustain agricultural development, farmers must acquire the capacity to respond to these changing situations and opportunities in order to maximize production. Farmers need to be helped to develop this capability through encouragement of the innovations they develop and by involving them in a learning process in which they are exposed to new knowledge and technologies. Therefore, strengthening their efforts through technical support and approaches is essential and must be enhanced. Drawing on these concepts, the participatory approach can be conceptualized as the interaction of individual farmers' fields and communal topo-sequence units (biophysical dimension) with the individual farmer or village community (human dimensions). This interaction determines the limits within which conservation technologies are physically possible, viable, and socially acceptable (suitable to individual and community goals).

Many technical solutions to soil erosion and land degradation exist but are developed without the genuine participation of the land user, do not build on local farmers' knowledge and joint dialogue between farmers and experts, and are not based on local erosion processes and controlling practices. A major change in awareness and sustainable natural resource management needs to occur, based on much wider adoption of locally available erosion indicators explored through interactive participatory approaches and integration of individual plot and topo-sequence units. Consequently, farmers need early warning indicators of erosion and monitoring tools to manage their land for better production, as the cost of preventing soil degradation is several times less than the cost of remedial actions. It is evident that in the process of participation and interaction farmers understand and gain knowledge of short-term erosion indicators in order to design protection measures before long-term impacts develop. Use of a combination of different short- and long-term erosion indicators is a useful means of gaining an overall impression of the land degradation situation and the limitations of soil conservation.

The methods and approaches applied and described here have provided improved soil and water conservation practices and innovations. They have also brought about positive impacts on the local knowledge and attitudes of farmers that are widely explored and utilized and can be integrated through dialogue with technical solutions provided by experts. In

addition, land users have been empowered through the ownership of erosion assessment, planning of conservation measures, implementing processes and sharing responsibilities. Action plans developed by land users through participatory and joint learning and action (involving trust-building meetings, continuous field visits and discussions, planning and implementing improved practices, and consensus building) became the means by which locally suitable and cost-effective soil conservation measures were improved, promoted and widely adopted. This also had an impact on generating innovative practices. These changes in practice are in fact highly affected by the skill, knowledge and commitment of the experts involved in joint learning actions and farmers' continuous dialogue and consensus. This land users' social learning approach suggests an alternative and/or preferable extension approach for achieving efficient and sustainable soil and water conservation under crop-livestock farming systems in the highlands of Ethiopia.

Lessons learned

- Exploring farmers' knowledge and experiences through joint farmer-expert learning and action motivates farmers to generate and adapt innovative ideas and practices
- Facilitating continuous participatory processes raises awareness and confidence among land users about becoming effective practitioners and helps to minimize their sense of dependency
- A focus on topo-sequence management is necessary to assess erosion and develop improved methods of sustainable land management
- The participatory and interactive approach reduces the workload and pressure on extension agents in the long run but requires well-trained agents for continuous dialogue and exchange of knowledge
- Some farmers have modified their practices and practice continuous adaptation to develop innovative practices that help to motivate neighbouring farmers
- Increasing farmers' understanding of short-term erosion indicators can orient them towards long-term erosion protection strategies
- The new approach helps to minimize farmers' sense of dependency and empower them

References

- Herweg, K., 1996. Field Manual for Assessment of Current Erosion Damage. Soil Conservation Research Programme (SCRIP), Ethiopia and Centre for Development and Environment (CDE), University of Bern, Switzerland.
- Hurni, H., 1986. Guideline for Development Agents on Soil Conservation in Ethiopia. CFSCDD, MOA, Addis Ababa, Ethiopia.
- Lakew Desta, Carucci, V., Asrat Wendem-Agegnehu and Yitayew Abebe (eds), 2005. Community Based Participatory Watershed Development: A Guideline (Part 1 and Part 2) Ministry of Agriculture and Rural Development (MOARD), Addis Ababa, Ethiopia.
- Mitiku, H., Herweg, K., Stillhardt, B., 2006. Sustainable Land Management – A New Approach to Soil and Water Conservation in Ethiopia. Mekelle, Ethiopia: Land Resources Management and Environmental Protection Department, Mekelle University, Bern, Switzerland: CDE, University of Bern, NCCR North-south, 269 pp.
- Nyssen J., Poesen, J., Mitiku H., Moeyersons, J. and Deckers, J., 2000. Tillage erosion on slopes with soil conservation structures in the Ethiopian highlands. Soil & Tillage Research 57: 115–127.
- Yohannes Gebre Michael and Herweg, K., 2000. From Indigenous Knowledge to Participatory Technology Development. Centre for Development and Environment (CDE), University of Bern, Switzerland .

Annex

A. Trust- and knowledge-based farmers' participation

- In the past, farmers' participation served to make extension planners and donors happy but was not based on genuine interest. Farmers must be aware and take responsibility through genuine participation in order to improve soil conservation and appropriate land management practices that will help to reverse recurrent crop production failures
- Farmers' participation does not mean attending meetings and campaign activities. Participation means proposing ideas and opinions for dialogue and discussion to bring about effective solutions to a given problem.
- Often farmers expect incentives or payments for planning and implementation of development activities on their land. In some areas this is the case to such an extent that participatory activities are not carried out without incentives. This expectation or dependency syndrome is the number one reason for the failure of many soil conservation projects in some areas. Farmers must therefore learn about and realize the impact of this dependency syndrome during participatory approaches in order to achieve sustainable land management solutions.
- It is often apparent that extension agents act as leaders of the development process and impose one-way decisions. This is another cause of less participation by farmers. Extension agents have a responsibility to convince farmers – through trust-building measures, continuous field visits, and discussions about the degradation of natural resources and their impact on future production and the environment as well as on their livelihoods.
- In general, it is appropriate to have regular and continuous discussions to create trust and responsibility among farmers in order to encourage them to conserve their land by themselves.

B. Formats for compiling erosion indicators and planned activities at plot level

Plot owner	Local erosion indicators	Causes	Damage/ impacts	Means of measurements of indicators	Planned measures	Subsequent improvements

C. Evaluation criteria for assessing the performance of stone terraces/soil bunds

S.N	Evaluation criteria	Responses	Additional remarks
1.	Construction time (years)		
2.	Lower side height during construction (cm)		
3.	Upper side height during construction (cm)		
4.	Vertical interval between terraces during construction (m)		
5.	Spacing between terraces during construction (m)		
6.	Do you think terrace construction was properly done?		
7.	Do you think there is enough construction material available in the locality?		
8.	How much labour do you think is required for maintenance?		
9.	Is damage liable due to free grazing?		
10.	Are natural shrubs grown along terraces? If yes, list their names		
11.	How long has the original storage capacity been filled by sediment?		
12.	Is the structure capable of retaining sediment washed from the terrace areas?		
13.	Is soil erosion a problem on the bottom side of terraces?		
14.	Is soil erosion a problem in the terrace area (between structures)?		
15.	Is there variation in crop growth within the terrace area?		
16.	Is there a change in soil texture, colour and depth within the terrace area?		
17.	Is there a need to maintain terraces annually?		
18.	What are the advantages and disadvantages of terraces in general? Which are more important?		
19.	What improvements would you suggest for terracing in the locality?		

D. Evaluation criteria for the assessment of traditional ditch performance

S.N	Evaluation criteria	Responses	Additional remarks
1.	How many ditches are there in the field (count)		
2.	For what purpose were the ditches are constructed?		
3.	Is there any damage at the outlet of ditches?		
4.	What changes were there in the dimensions (depth, width, length) of the ditches compared to initial dimensions?		
5.	How steep is the gradient of the ditch?		
6.	If the gradient of the ditch is reduced or becomes gentle, will problems result?		
7.	Do you think that the gradient should be reduced?		
8.	What would happen to the land if there were no ditches at all?		
9.	Compare land with ditches and without ditches		
10.	What damage occurred on the downslope plots?		
11.	Is there any conflict between adjacent farmers due to ditch erosion? How do you avoid such conflict?		
12.	Is the advantage or disadvantage more important?		
13.	What possible improvements could be made for an effective ditch system?		

E. Monitoring and recording of continuous improvements in soil and water conservation measures at individual plot and landscape levels

Plot owner/ common lands	Length of new terraces (m)	Maintenance or terrace improvements (m)	Check dams (count)	Waterways (m)	Trenches (count)	Biological measures



ESAPP

u^b
UNIVERSITÄT
BERN
CDE
CENTRE FOR DEVELOPMENT
AND ENVIRONMENT